# Using a GIS to Determine how Different Types of Land Cover have Changed over Time in the State of Connecticut

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## Abstract

This project focuses on how agricultural land cover has changed over time in comparison to developed and turf/grass land cover areas. This was done for two areas, the State of Connecticut and the area of Hartford County, Connecticut. This project defines specific areas in which agricultural land cover have changed to another type of land cover between the years 1985 and 2006. Changes to developed and turf/grass areas were determined as well, in order to show the amount of changed agricultural areas that became developed areas or turf/grass areas. In addition to spatial analysis methods, several statistical analysis methods were performed on the data. Statistical analysis methods were implemented in order to show the relationships that existed among the developed land cover data and the turf/grass land cover data with respect to the agricultural data.

## Introduction

According to the Connecticut Farmland Trust, the state of Connecticut has been losing an average of 8000 acres of farmland each year. These former agricultural areas were converted to areas supporting the building of new infrastructure, including the expansion of new areas to build residential housing and commercial businesses. This dramatic land cover change caused twenty-one percent of the agricultural land in the state to be lost over the past twenty years. If this rate of change continues, it has been projected that the remaining farmland in the state would be depleted within the next two generations (Connecticut Farmland Trust, 2005).

### *Project Definition*

The purpose of this project was to determine how the acreage of agricultural land cover, developed land cover and turf/grass land cover in the State of Connecticut and in the area of Hartford County, in acres, has changed over time. This project also evaluated the results of these changes and attempted to determine if these changes in land cover types were directly related to each other. This was done through spatial and statistical analysis methods.

### *Study Area*

There were two study areas used for this project. The first study area was the State of Connecticut. The second study area was the area of Hartford County, Connecticut. The study area of Hartford County was chosen because this area of the state had a high occurrence of agricultural land cover data. Two study areas were used for this project because the results for each of the study areas were compared to each other in order to determine the similarities and differences between the results. Two study areas were also used to compare the statewide results of

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the project to the results at the county level. The following figures display the two study areas used for this project (Figures 1 and 2).

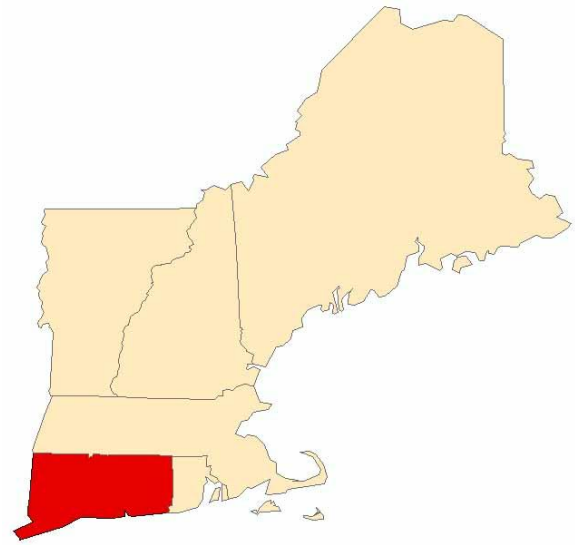

Figure 1. The study area of the State of Connecticut (shown in red) with respect to the area of New England, which is located in the northeastern area of the United States.

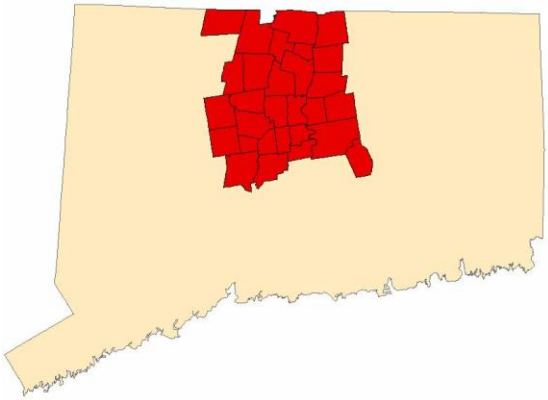

Figure 2. The study area consisting of the town boundaries of Hartford County, Connecticut (shown in red) with respect to the State of Connecticut.

## Project Methodology

### *Data Collection Process*

The data used for this project were land cover maps for the state of Connecticut. Data for this project were obtained from the University of Connecticut (UConn) Center for Land Use Education and Research (CLEAR) website. The data used were from Connecticut's Changing Landscape project which classified the state of Connecticut into eleven land cover categories.

For this project, five raster images from the UConn CLEAR website were downloaded. These images contained land cover information for the state of Connecticut for the years of 1985, 1990, 1995, 2002 and 2006. In each of these images, each cell was classified into one of the eleven land cover categories. Each individual cell was 100 by 100 feet, giving one cell a total area of 10,000 square feet.

In addition, several vector data layers were used in this project. Vector datasets of the counties and towns in Connecticut were used as reference images in the final map layouts of the project.

### *Data Preparation*

Geodatabase Creation

Two folders and a file geodatabase were created to store the data for this project. One folder was created for temporary data created during the project and a second folder was created in order to store final raster output images. A file geodatabase was also created, in order to store the vector background information and the final results that were used for map layouts.

Preparation of Raster Data

Before data analysis was performed on the raster data, the background information from the images was removed. This was done by selecting all of the layers in each of the raster datasets except for the background layer. The selected data was then exported as a new raster image. This process

removed most of the unnecessary background data from each of the five original raster images.

Data Projection

To ensure that all of the raster and vector data would align spatially, all of the data were projected in the same coordinate system. The data used in this project were projected in the following coordinate system:

Spatial Reference:
NAD_1983_StatePlane_Connecticut_FIPS_0600_Feet
Linear Unit: Foot_US
Angular Unit: Degree
Datum: D_North_American_1983

Projected Coordinate System:
NAD_1983_StatePlane_Connecticut_FIPS_0600_Feet
Projection: Lambert Conformal Conic
Geographic Coordinate System:
GCS_North_American_1983

***Spatial Analysis***

Although there were eleven land cover categories in the raster datasets, it was determined that not all of these land use classes were needed for the project. The land cover categories of agricultural field, developed and turf/grass areas were used for this particular project.

The agricultural land cover land type referred to areas being used for agricultural purposes, with uses which included crop production and/or active pasture. Developed land was high-density built up areas. These areas included transportation routes as well as residential, commercial and industrial areas. Turf/grass areas referred to different types of maintained grasses that were generally associated with developed areas. Land in these types of areas contained cultivated lawns which would be found in areas such as residential areas, parks, cemeteries and golf courses (UConn CLEAR, n.d.).

Change in Specific Land Cover Types

The first stage of the analysis process involved the selection of three land cover categories to be used in the project and the calculation of the amount of change for each type of land cover data. The raster calculator in the spatial analyst toolbar was used to select each of the land cover types from each of the original images. In each raster image, agriculture had a land cover code of four, developed areas had a land cover code of one and turf/grass areas had a land cover code of two. The calculations performed for the 1985 data are shown below:

[1985_data] == 4 (Agriculture)
[1985_data] == 1 (Developed)
[1985_data] == 2 (Turf/Grass)

These new layers showed the agricultural areas, developed areas and turf/grass areas from the original 1985 data. This process was repeated for the other four original raster images. The other land use codes in the raster images were not selected since they were not utilized in this project.

These layers were then used to calculate the amount of change within each of the land cover categories. The change in land use was calculated by dividing the total area in one of the output layers displaying the selected type of land use by the total area in the next output layer displaying the same type of land use. For example, the percentage change in agricultural land cover was calculated by dividing the 1985

agricultural data by the 1990 agricultural data. This was also done for 1990 to 1995, 1995 to 2002 and 2002 to 2006. A total change percentage from 1985 to 2006 was also calculated. The total amount of change was calculated for the other two land cover types as well.

Calculating Change in Agricultural Areas to Developed and Turf /Grass Land Cover Types

The second stage of the spatial analysis was to determine how much of the changed agricultural land had become either developed or turf/grass land cover types. For each of the following steps described below, the raster calculator in the spatial analyst toolbar was used.

The first step was to subtract the 1985 agricultural areas from the 2006 agricultural areas, which produced the total change in agriculture.

Next, the 2006 developed areas were subtracted from the 1985 agriculture areas, which produced the total change in developed areas.

The third step was to subtract the 2006 turf /grass areas from the 1985 turf/grass areas, which showed the total change in turf/grass areas.

An analysis mask was used in the next two steps of this process, which was used to select areas that were contained in a raster image. Any of the results that were not contained in the analysis mask layer were not included in the selection output.

In the fourth step, an analysis mask of the total change in developed areas was used. This step determined the change from agriculture to developed land use areas by selecting the total change in agricultural areas having a value equal to -1 and the total change in developed areas having a value equal to -1.

The fifth step used an analysis mask of the total change in turf/grass areas. This step determined the change from agriculture to turf/grass land cover areas by selecting the total change in agricultural areas having a value equal to -1 and the total change in turf/grass areas having a value equal to -1.

In the last step of this process, no analysis mask was used. This step selected the total change from agriculture to developed land cover areas having a value equal to -1 or the total change from agriculture to turf/grass land cover areas having a value equal to -1. This step showed the total change from agriculture to developed and turf/grass land cover areas.

The figure on the following page shows a model of the process used in the second stage of the spatial analysis process. This model shows the output raster images created from each of the intermediate steps and the final output (Figure 3).

The next portion in this stage of the analysis process was to determine the percentage of agricultural areas that had changed to developed or turf/grass areas. This was done by dividing the total area in the total change from agricultural to developed land cover areas and turf/grass land cover areas layer by the total area in the total change in agriculture layer.

***Statistical Analysis***

In order to determine the relationships among the three land cover types, two statistical methods were used on the data. To determine if the decrease in agriculture land cover was directly related to the increase in developed and turf/grass land cover areas, a correlation and a regression analysis were performed on the data. For both analysis methods, the Statistical Package for Social Sciences (SPSS) software package was used.

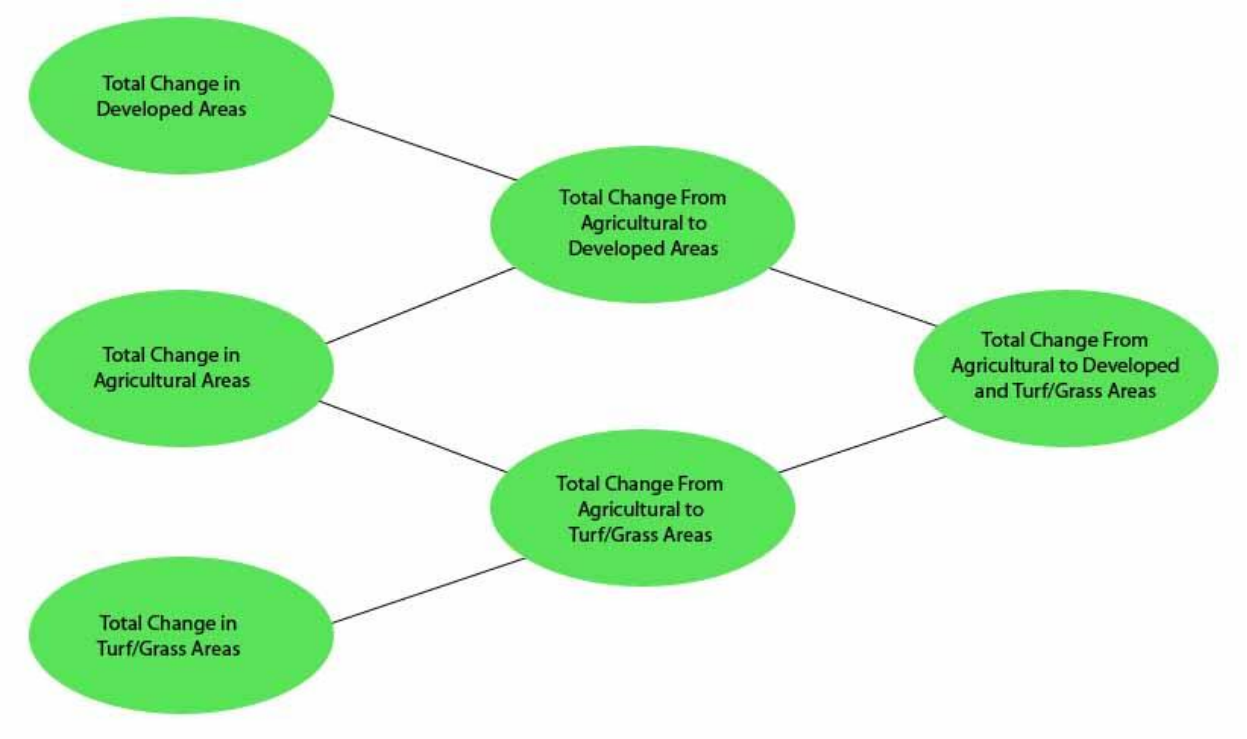


Figure 3. The resulting raster images created from the second stage of the analysis process.

Correlation Analysis

The correlation analysis in this project measured the relationship between three variables: agricultural land cover, developed land cover and turf/grass land cover. A bivariate correlation analysis was performed on the three variables in order to determine if the decrease in agricultural land cover was inversely related to the increase in developed land cover or turf/grass land cover (Zar, 2010).

Regression Analysis

The regression analysis in this project was used to determine the best way to predict the change in either developed land cover or turf/grass land cover over time based on trends in agricultural land cover. A multiple regression analysis was performed on the data in order to determine the relationship between agricultural land cover data and the other two types of land cover data (Zar, 2010).

A linear regression was performed in SPSS in order to calculate the regression equations. The dependent variable was the agricultural land cover areas and the independent variables were the developed land cover and the turf/grass land cover areas. A stepwise method was chosen for the method type.

Once the analysis process was run for each of the study areas, several output tables were created. The coefficients output table was used in order to determine the regression equation for each of the study areas.

## Results

### *Spatial Analysis*

Change in Specific Land Cover Types

For the first stage of the spatial analysis process, three land cover categories were selected from each of the five original raster images. The following table shows the amount of land, in acres, for the State of Connecticut for each of the three land cover types (Table 1).

Table 1. The amount of area in acres for each land cover type in the study area of the State of Connecticut.

| | Agriculture | Developed | Turf/Grass |
|---|---|---|---|
| 1985 | 272209.2 | 511233.5 | 197883.7 |
| 1990 | 258578.4 | 552937.2 | 208702.6 |
| 1995 | 250879.9 | 567753.2 | 218781.5 |
| 2002 | 238070.2 | 591714.8 | 232122.8 |
| 2006 | 232653.8 | 604098.1 | 244424.6 |

The area for the second study area was calculated as well. The following table shows the amount of land for each of the three land cover types in the area of Hartford County, Connecticut (Table 2).

Table 2. The amount of area in acres for each land cover type in the study area of Hartford County.

| | Agriculture | Developed | Turf/Grass |
|---|---|---|---|
| 1985 | 53860.44 | 108753 | 44085.22 |
| 1990 | 49161.19 | 119921 | 45271.86 |
| 1995 | 46880.90 | 123155.4 | 46598.30 |
| 2002 | 42880.68 | 128684.3 | 48754.63 |
| 2006 | 40993.18 | 131698.7 | 51070.50 |

The data from the first two tables were then used to calculate the percentage change of the various land cover categories. The following table shows the percentage of change within each land cover category for the State of Connecticut (Table 3).

Table 3. The percentage of change between each of the raster images for the study area of the State of Connecticut.

| | Agriculture | Developed | Turf/Grass |
|---|---|---|---|
| 1985-1990 | -5.271% | 7.542% | 5.208% |
| 1990-1995 | -3.069% | 2.610% | 4.607% |
| 1995-2002 | -5.831% | 4.050% | 5.748% |
| 2002-2006 | -2.328% | 2.050% | 5.033% |
| 1985-2006 | -17.002% | 15.372% | 19.061% |

For the second study area of Hartford County, the percentage of change between the land cover categories was calculated as well. The following table shows the amount of change in land for the area of Hartford County, Connecticut (Table 4).

Table 4. The percentage of change between each of the raster images for the study area of Hartford County.

| | Agriculture | Developed | Turf/Grass |
|---|---|---|---|
| 1985-1990 | -9.559% | 9.313% | 2.621% |
| 1990-1995 | -4.864% | 2.626% | 2.847% |
| 1995-2002 | -9.329% | 4.296% | 4.423% |
| 2002-2006 | -4.604% | 2.289% | 4.535% |
| 1985-2006 | -31.389% | 17.423% | 13.678% |

## Calculating Change in Agricultural Areas to Developed and Turf/Grass Land Cover Types

For the second stage of the spatial analysis process, several new raster images were calculated using the raster calculator in the spatial analyst toolbar. In this portion of the

analysis process, the total change in developed land cover and turf/grass land cover was compared to the total change in agricultural land cover. Through the use of the raster calculator, this portion of the spatial analysis produced several raster output images. The final output of this process showed the total change from agricultural land cover to developed and turf/grass land cover. The figures on this and the following page show the final output raster image compared to the total change in agricultural land cover. This is shown for the State of Connecticut as well as the study area of Hartford County (Figures 4 and 5).

Once these two raster images were produced, the total change from agricultural to developed and turf/grass land cover areas was divided by the total change in agricultural land cover areas. Based on the total area in the resulting raster images, it was calculated that 65.45% of agricultural land cover that had changed over time in the State of Connecticut had changed to either developed land or turf/grass areas. For the study area of Hartford County, it was calculated that 56.02% of agricultural land cover areas had changed into developed or turf/grass land cover areas.

In order to show the greatest amount

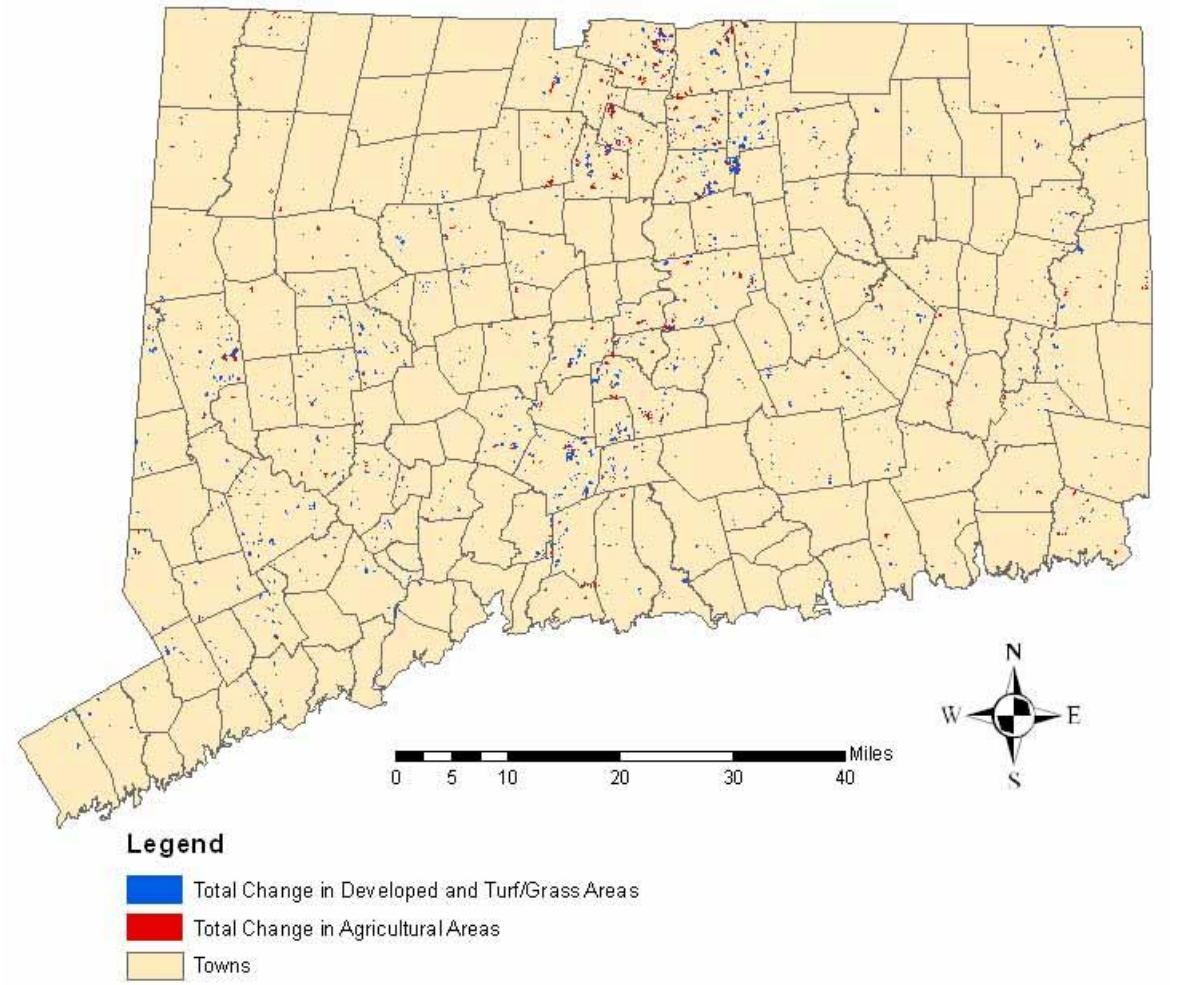


Figure 4. The total change in agricultural land cover areas compared to the total change in developed and turf/grass land cover areas in the State of Connecticut.

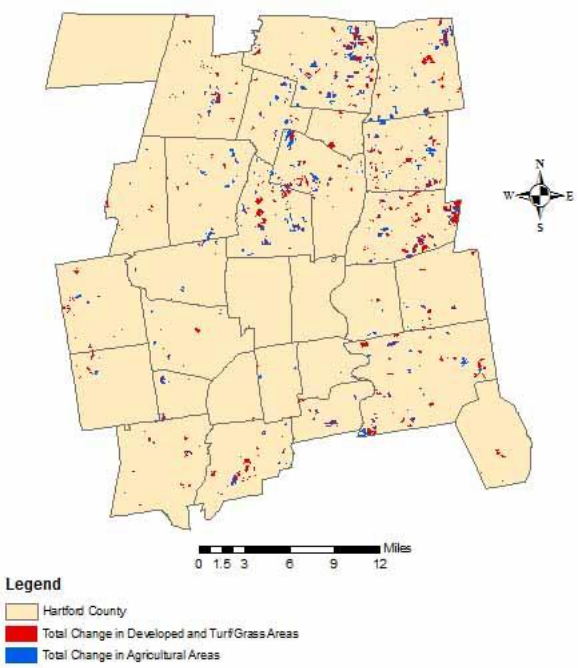


Figure 5. The total change in agricultural land cover areas compared to the total change in developed and turf/grass land cover areas in the study area of Hartford County, Connecticut.

of change, the total change from the 1985 data to the 2006 data was used. This was done in order to show the greatest amount of change within the data among the greatest amount of time.

### *Statistical Analysis*

In this project, two types of statistical analyses were performed along with the spatial analysis methods. The statistical portion of this project was done in order to show the relationship between the three land cover types that were being observed in this project.

Correlation Analysis

The correlation analysis was used to determine if there was an inverse relationship between the decrease in agricultural land cover areas and the increase in developed and turf/grass land cover areas.

Once the data were entered into SPSS, a bivariate correlation was performed for each of the three land cover types. The following figures show the results of the correlation analysis for the State of Connecticut and for Hartford County (Figures 6 and 7).

**Correlations**

| | | Agriculture | Developed | Turf_Grass |
|---|---|---|---|---|
| Agriculture | Pearson Correlation | 1 | -.993** | -.988** |
| | Sig. (2-tailed) | | .001 | .002 |
| | N | 5 | 5 | 5 |
| Developed | Pearson Correlation | -.993** | 1 | .970** |
| | Sig. (2-tailed) | .001 | | .006 |
| | N | 5 | 5 | 5 |
| Turf_Grass | Pearson Correlation | -.988** | .970** | 1 |
| | Sig. (2-tailed) | .002 | .006 | |
| | N | 5 | 5 | 5 |

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 6. Correlation values for the State of Connecticut.

**Correlations**

| | | Agriculture | Developed | Turf_Grass |
|---|---|---|---|---|
| Agriculture | Pearson Correlation | 1 | -.990** | -.967** |
| | Sig. (2-tailed) | | .001 | .007 |
| | N | 5 | 5 | 5 |
| Developed | Pearson Correlation | -.990** | 1 | .929* |
| | Sig. (2-tailed) | .001 | | .023 |
| | N | 5 | 5 | 5 |
| Turf_Grass | Pearson Correlation | -.967** | .929* | 1 |
| | Sig. (2-tailed) | .007 | .023 | |
| | N | 5 | 5 | 5 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 7. Correlation values for the area of Hartford County.

For the state of Connecticut, the results of the SPSS calculations showed that there was a -.993 correlation between agricultural land and developed land. Also, there was a -.998 correlation between agricultural land and turf/grass land.

For the area of Hartford County, the results of the correlation analysis showed that there was a -.990 correlation between agricultural land and developed land. A correlation of -.967 was calculated between agricultural land and turf/grass land.

These results showed that there was

an almost perfect inverse relationship between agricultural land cover and the other two land cover categories. The negative correlation produced by the results showed that for each unit of decrease in one land cover type, the other land cover type would increase by almost the same amount.

Regression Analysis

The regression analysis for this project produced one equation for each study area. For both of the study areas, agricultural land cover data was compared to developed land cover data and turf/grass land cover data. These equations were used to determine the relationships between the three variables and how they were affected by each other.

For the State of Connecticut, the data were graphed in order to visualize the regression equation. The following figure shows the graph for the first study area comparing agricultural and developed land cover data (Figure 8).

The data were also graphed for the State of Connecticut showing the relationship between agricultural land cover data and turf/grass land cover data (Figure 9).

These variables were graphed for the second study area as well. These graphs

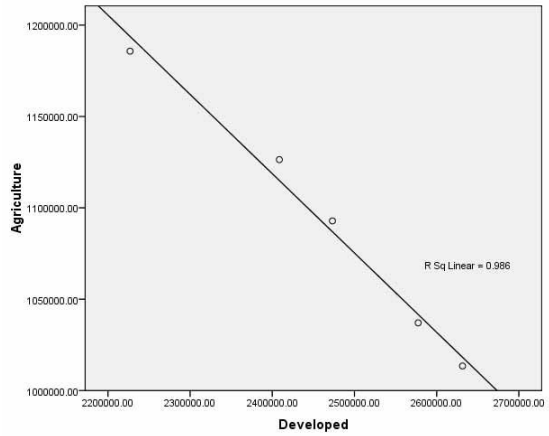


Figure 8. Graph of agricultural and developed data in the State of Connecticut.

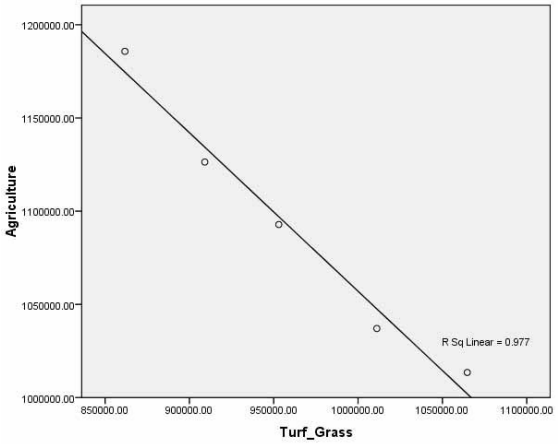


Figure 9. Graph of agricultural and turf/grass data in the State of Connecticut.

were not included since they were very similar to the graphs created for the first study area.

The regression analysis resulted in two equations, one for each study area. For the Connecticut regression analysis, several tables were produced in SPSS. The following figure shows the SPSS output for the State of Connecticut (Figure 10).

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. |
| 1 | (Constant) | 2.160E6 | 74472.660 | | 29.006 | .000 |
| | Developed | -.434 | .030 | -.993 | -14.379 | .001 |

a. Dependent Variable: Agriculture

**Excluded Variables[b]**

| Model | | Beta In | t | Sig. | Partial Correlation | Collinearity Statistics |
|---|---|---|---|---|---|---|
| | | | | | | Tolerance |
| 1 | Turf_Grass | -.428[a] | -2.567 | .124 | -.876 | .060 |

a. Predictors in the Model: (Constant), Developed

b. Dependent Variable: Agriculture

Figure 10. Multiple regression output results for the State of Connecticut.

The coefficients table from the results shows the regression equation generated from the three land cover types. Based on the results from the coefficients table, the regression equation for the State of Connecticut was determined to be the following equation:

$$Y = 2160000 - .434\text{Developed}$$

Although a multiple regression analysis was used, the final equation only contained two variables. This is because SPSS excluded the turf/grass variable, determining that the third variable did not have enough impact on the agriculture variable to affect it.

The same process was done for the Hartford County study area. The following figure shows the SPSS output for the Hartford County multiple regression analysis (Figure 11).

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. |
| 1 | (Constant) | 505987.355 | 24691.187 | | 20.493 | .000 |
| | Developed | -.567 | .046 | -.990 | -12.270 | .001 |

a. Dependent Variable: Agriculture

**Excluded Variables[b]**

| Model | | Beta In | t | Sig. | Partial Correlation | Collinearity Statistics |
|---|---|---|---|---|---|---|
| | | | | | | Tolerance |
| 1 | Turf_Grass | -.342[a] | -3.053 | .093 | -.907 | .137 |

a. Predictors in the Model: (Constant), Developed

b. Dependent Variable: Agriculture

Figure 11. Multiple regression output results for the area of Hartford County.

The coefficients table from the results shows the regression equation for the second study area. The regression equation for the Hartford County study area is shown below:

$$Y = 505987.355 - .567\text{Developed}$$

In the second study area, only the agricultural and developed land cover variables were used in the regression equation. Once again, this is because the turf/grass variable did not have enough of an effect to influence the other two variables.

## Conclusion

This project used a GIS in order to determine if the decrease in agricultural land cover was directly related to the increase in developed and turf/grass land cover. This hypothesis was tested for the study areas of the State of Connecticut and for the area of Hartford County, Connecticut.

It was determined through spatial analysis that 65.45% of agricultural land from 1985 to 2006 had become either developed or turf/grass land cover types in the State of Connecticut. In the Hartford County area, it was determined that 56.02% of the agricultural land had been converted into these other two land cover types.

Through the use of statistical analysis methods, it was determined that the decrease in agricultural land was inversely related to the increase in developed land and turf/grass areas. The correlation analysis showed that there was almost a perfect inverse relationship between agricultural land cover data and developed land cover data. This was also found for agricultural land cover data and turf/grass land cover data. The regression analysis produced an equation for each study area describing the relationship comparing the agricultural land cover data to the developed land cover data and the turf/grass land cover data. In each of the two regression equations produced, there was a high correlation between agricultural and developed land cover data, but not turf/grass land cover data.

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